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Characterization Of Water Quality In Anzalduas Dam Reservoir Using Patterns Of Salinity

Maria G. Castillo

CHARACTERIZATION OF WATER QUALITY IN ANZALDUAS DAM RESERVOIR USING PATTERNS OF SALINITY

by

Maria G. Castillo
Bachelor of Industrial Chemistry, Universidad Autonoma de Tamaulipas Mexico, 1981
Bachelor of Technology Management, South Texas College, 2010
Master in Higher Education Administration and Leadership, Adams State University, 2017

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Name: Maria G Castillo

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This document, submitted in partial fulfillment of the requirements for the degree from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

DocuSigned by: Yeo Howe Lim

Yeo Howe Lim

DocuSigned by: Taufique Mahmood

Taufique Mahmood

DocuSigned by: Michael Mann

Michael Mann

This document is being submitted by the appointed advisory committee as having met all the requirements of the School of Graduate Studies at the University of North Dakota and is hereby approved.

DocuSigned by: Chris Nelson

Chris Nelson
Dean of the School of Graduate Studies

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Maria G. Castillo
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ABSTRACT

A database containing salinity and climatology data collected at Anzalduas Dam's Reservoir, Mier Monitoring Station (Upper water from Anzalduas Dam) and Retamal Monitoring Station (Lower water from Anzalduas Dam) in the lower Rio Grande River for the September through December 2016 time period was compiled. The information obtained on the water quality of Anzalduas Dam was used as a base to describe corrective measurements needed for its water recuperation, improvement and/or contamination's prevention. The study aims to illustrate the relationship between water quality, specifically focusing on salinity concentrations and its relationship with temperature, evaporation, and the volumetric rate of water flow (Q).

Salinity and climatology data were then analyzed using descriptive statistics to determine their plausibility. After that, the data were used in ANOVA variability and regression analyses to determine the relationship of salinity with water quality in irrigation water. All analyses and parameters were averaged over one, two, and three months.

Salinity patterns were very similar during those three months in Anzalduas Dam reservoir; however, the daily mean on salinity exhibited greater variability. The mean salinity concentration obtained in an afternoon was typically lower when compared with the morning period. Those differences in salinity concentrations are related to the increase of flow rate during the seasonal irrigation. It may be accounted for by dilution.

CHAPTER 1

INTRODUCTION

Despite the importance of the water quality on Anzalduas Dam over the possible ecological impacts of salinity, only a few detailed analyses of salinity patterns have been performed. Physical monitoring on both sides of the International Dam is a dangerous activity due the insecurity on the Mexican side of the dam during the present decade. "One man shot dead and two injured after gunman opens fire on 'American fishing boat' on the Rio Grande 'from the Mexican side of the border'" reported the Daily Mail (2017). In a clearly description of the Anzalduas Dam daily activities, Kelley, R. (2017) stated: "An effort by humankind to tame the river's devastating past floods and bring irrigation to the often-arid farmland on both sides of the boundary river that separates Mexico and the United States".

Figure 1. Map of Anzalduas Dam. Data from Google Maps.

A microcosm of that long international border is found in the control room of Tower 4 at the Anzalduas Dam near Mission, TX. It is the middle tower of seven that contains six gates that are 75 feet wide by 21 feet high, and weigh approximately 140 tons a piece. In the room, which is approximately 35 feet by 12 feet wide, a phantom border separates the two countries and the operators of the dam, one from Mexico, the other from the United States. The walls of the room are lined with monitors, recording and spewing back flow rates and other data used to monitor the dam.

Figure 2. Anzalduas Dam, Mission, TX

(Source: US IBWC.gov/MissionOperations/Anzalduas)

CHAPTER 2

RESEARCH PROPOSAL

The region of study is the Rio Grande River in the South of Texas in the area located at Anzalduas Dam in Mission, TX. The International Boundaries and Water Commission (IBWC) United States and Mexico Mexican Section, which is the binational federal agency to monitor the Rio Grande, has large data base on salinity and climatology on the International Anzaldua Dam. The International Boundaries and Water Commission bold his mission: "Our mission is to provide binational solutions to issues that arise during the application of United States-Mexico treaties regarding boundary demarcation, national ownership of waters, sanitation, water quality, and flood control in the border region". Based in the IBWC daily information, one detailed study on salinity has been performed on the data compiled from September through December, 2016 using telemetric equipment.

In this study, the water quality at Anzalduas Dam was studied using observation of salinity concentrations through collecting electric conductivity and climatology data from September - December 2016.

2.1 Research Hypothesis

The primary research hypothesis for this study is: The concentration of salinity and its relationship with temperature, evaporation and the volumetric rate of water flow (Q) are essential values for the characterization of water quality in Anzalduas Dam.

Salinity concentration values are important to determine the environmental and economic impacts in Anzalduas Dam because the Rio Grande River's water is used by both countries, USA and Mexico, as its water is used both for water purification plants for human's consumption and as irrigation water.

The salinity concentration value is an especially important parameter to determine the water quality in the Anzalduas Dam because the water of the dam is mainly used directly, without treatment, for irrigating vegetables and fruits, and high salinity values can have a detrimental impact of the crops being irrigated.

The work done in this study was designed to confirm or reject the hypothesis stated above.

2.2 Research Objectives

The research objectives are to demonstrate the water quality based on salinity concentrations analyzing the database with descriptive statistics. The salinity database includes climatology data such as temperature, evaporation and the volume rate of water flow (Q) and its relationship with time. The dataset used for this study was covered the period from September – December 2016.

Database analysis:

- Analyzed using descriptive statistics to determine its feasibility: Box plots, Histogram and Normal Distribution

Salinity database:

- Examined using ANOVA, Simple Linear Regression and variability of Salinity versus Time,

Climatology database versus time:

- Evaluated Temperature versus (vs) Time, Evaporation vs Time, Volume Rate vs Time

2.3 Thesis Outlines

Chapter 3 provides a review of existing literature on salinity definitions, the importance of salinity data in the Rio Grande and other studies based in the state of water quality focusing on salts and trace elements were reviewed.

Chapter 4 describes the study area and the data. It introduces the monitoring stations, and dates of record and components analyzed in the monitoring sites. Data used in this study was also listed in this chapter.

Chapter 5 is the methodology of salinity used in the research. In this section descriptive statistics' calculations in salinity were introduced.

Chapter 6 shows data obtained in the monitoring station- Hidalgo, TX 6 miles downstream of the Anzalduas Dam. Data of specific conductance and temperature were displayed.

Chapter 7 shows the results in salinity and climatology based in descriptive statistics, statistics, and variability.

Chapter 8 discussed the research hypothesis based in the results of this study.

Chapter 9 consist of conclusions, limitations and recommendations for future work at Anzalduas Dam.

CHAPTER 3

LITERATURE REVIEW

3.1 Definition of salinity

Salinity refers to the total concentrations of all dissolved salts in water. Since salts form ionic particles when dissolved, it is a strong component of conductivity. Also, salinity is an important water quality measurement as it affects the basic chemistry of water as well the biological process that occur within it (Instrumart, 2017).

Salinity concentration effects are especially important in determining damage to sensitive species of vegetables and plants. "Most salinity problems in agriculture result directly from the salts carried in the irrigation water. In most irrigation situations, the primary water quality concern is salinity levels, since salts can affect both the soil structure and crop yield" (Fipps,(1998), p.4).

Water salinity is usually measured by the EC (electric conductivity). EC is actually a measurement of electric current and is reported in one of the three possible units as given in Table 1.

Table 1. Terminology and units for water salinity.

Symbol Total Salinity	Meaning	Units
EC	Electric conductivity	µmhos/cm, mmhos/cm dS/m
TDS	Total dissolved solids	Mg/L and ppm

Salinity and climatology analyses were evaluated because they may cause environmental and economic impacts on the lower water of the Anzalduas Dam through the Rio Grande River's flow.

Figure 3 provides an overview of the types of analyses that can be performed to evaluate the water quality of the Anzalduas Dam.

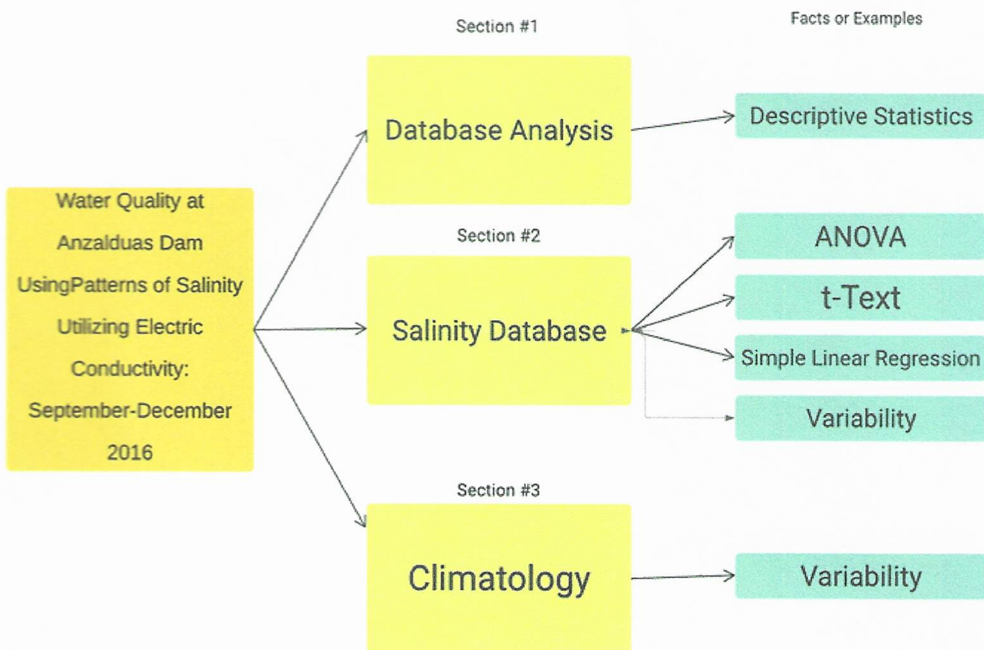

Figure 3. The water quality at Anzalduas Dam and its study's sections

The area of study is the Rio Grande Valley located in the south of Texas. It is a rural agriculture area that uses the water of the Anzalduas Dam as irrigation's water in the crops of onions, lettuce, cucumbers, citrus, sugar cane, potatoes, spinach and in summer cantaloupes and watermelons. Table 2 shows the irrigation water salinity tolerance for different crops.

Table 2. Irrigation water salinity tolerances for different crops

(Adapted from Ayres and Westcot, 1976)

	Yield Potential, ECiw			
Crop	100%	90%	75%	50%
Cabbage	1.2	1.9	2.9	4.6
Cantaloupe	1.5	2.4	3.8	6.1
Carrot	0.7	1.1	1.9	3.1
Cucumber	1.7	2.2	2.9	4.2
Lettuce	0.9	1.4	2.1	3.4
Onion	0.8	1.2	1.8	2.9
Pepper	1.0	1.5	2.2	3.4
Potato	1.1	1.7	2.5	3.9
Radish	0.8	1.3	2.1	3.4
Spinach	1.3	2.2	3.5	5.7
Sweet Corn	1.1	1.7	2.5	3.9
Sweet Potato	1.0	1.6	2.5	4.0
Tomato	1.7	2.3	3.4	5.0

Note: ECiw is the electric conductivity of the irrigation water measured in mmhos/cm

Other reviews reported the flow of the Rio Grande and the state of water quality focusing on salts and trace elements (Miyamoto et al, 1995). The researchers affirmed that "The adverse effect of salts on crops productions varies with salt tolerance of crops, salinity control in the root zone and several other factors". (Miyamoto et al, 1995) declared that the major agricultural water use of the Rio Grande are sourced below Falcon Dam and it accounts for 88 percent of the Rio Grande irrigated area on the Texas side, and 96 percent of the land irrigated directly by the Rio Grande on the Mexican side. Water from Anzalduas Dam reservoir is one of the most important sources of water used in the irrigation in Reynosa, Mexico and Mission, TX. It is interesting to know the predictions based on salinity trends and the annual flow for the lower Rio Grande appointed by previous studies in the Rio Grande River. "Salinity increases at Falcon as well as Laredo were somewhat modest, 0.015 dSm per year (or 7.8 mgL per year). If this trend continues, salinity at Falcon is projected to reach 1.34 dS m^{-1} (885 mg l^{-1}) by the year 2000". Falcon is 220 miles from Anzalduas Dam.

The scientists used the annual mean salinity to examine salinity trends, the annual mean salinity readings were fitted to the linear regression equation:

$$EC = a(X-1969) + b$$

where EC is the annual mean salinity in dS m^{-1}

X is the years since 1969, which was the year of the study.

a and b are regression coefficients.

Table 3. Linear Regression using equation EC = a(X-1969) + b since 1969 at various locations along the Rio Grande.

Location	River	Slope dS m-1/year	r	Intercept	1990 dS m-1	2000
El Paso	Rio Grande	-0.023	-0.57	1.78	1.30	—
Fort Quitman	Rio Grande	-0.216	-0.71	8.03	3.28	—
Ojinaga	Rio Grande	0.013	0.68	1.14	1.40	1.54
Presidio	Rio Grande	0.029	0.80	1.20	1.81	2.10
Foster Ranch	Rio Grande	0.022	0.89	0.84	1.30	1.52
Langtry	Rio Grande	0.061	0.64	2.59	3.87	4.48
Amistad	Rio Grande	0.023	0.89	0.81	1.29	1.52
Laredo	Rio Grande	0.014	0.78	0.89	1.19	1.33
Falcon	Rio Grande	0.015	0.79	0.88	1.20	1.34=885 mgl^{-1}
Camargo	Rio San Juan	0.032	0.40	1.56	2.24	—
Brownsville	Rio Grande	-0.0035	0.16	1.39	1.46	—

Note: Data from IBWC.

3.2 Linear regression data

Analyzing Anzalduas Dam salinity's concentration and following the linear regression it is interesting to note that it concludes of that the salinity concentration on Anzalduas Dam will be increasing with time. After substituting values from 2016 on salinity and flow rate data in the linear regression equation, the statistic results are established.

The formula is the following:

$$Y=865.0 - 1.12\,X.$$

where Y is the concentration of salinity estimated

X= predictor in years. Six years it is the value of X.

The result after using the simple linear regression based in a value of salinity of 865 mg/L as it is shown in Table 4.

Table 4. Simple linear regression from salinity data 2016

Linear Regression between Salinity Mean and Volume Low Rate:					
"(intercept(C4:C94,I4:I94)		864.86			
"slope =		-1.115141			
RSQ =		0.026251			
STEYX		60.87239	**The estimated model is Y = 864.86 - 1.11514 X**		
Forecast =		858.1763			
The forecast model for X=6					
Y = 864.86 - 1.115115 *6 = 858.17					

Note: X = 6 is measured in years

The projected value of salinity is 858.17 mg/L in the year 2022

CHAPTER 4

STUDY AREA AND DATA AVAILABILITY

4.1 Study Area

The study area of this research includes the Anzalduas Dam and Table 5 lists latitude and longitudes of the monitoring stations found in the area.

Table 5. Location of monitoring stations in the Anzalduas Dam area.

Symbol	Site	Latitude	Longitude
A	Telemetric Station (IBWC) Mexico-CILA "Mier" Station. Upper stream from Anzalduas Dam	26.450433°	-99.152431°
B	Telemetric Station in the center of the dam (IBWC) - USA	26.1376°	-98.3351
C	Telemetric Station in the center of the dam – (IBWC) Mexico-CILA	26.1376°	-98.3351
D	Telemetric Station (IBWC)Mexico-CILA "El "Retamal" Station. Lower stream from Anzalduas Dam	26.044593°	-98.031336°

Note. Monitoring stations located upper stream and lower stream from Anzalduas Dam and the three monitoring stations at Anzaldua Dam's reservoir. Data from IBWC. Mexico (CILA).

4.2 Data Compilation and Screening

Salinity data were monitored by the IBWC Mexican Section (CILA) and the US IBWC at Anzalduas Dam's reservoir. Temperature, evaporation and Q data were compiled from CILA, Mexican section. The salinity monitor's form described three hourly period of lectures on salinity every day in the dam's reservoir during the following hours: 6:00 AM, 12:00 PM and 6:00 PM. The monitor for the hours of 6:00 AM and 16:00PM were registered by the US IBWC and the monitor corresponding at 12:00 PM was registered by CILA. Table 6. Shows the dates and components analyzed at each of the monitoring sites.

Table 6. Dates of record and components analyzed at the monitoring sites

Site	Start	End	Salinity	Q	T	Evaporation
	(mm-dd-yyyy)	(mm-dd-yyyy)	(ppm)	(m3/s)	°C	(mm)
Mier	09-01-2016	11-30-2016	X	X	X	X
Anzalduas Dam	09-01-2016	11-30-2016	X	X		
Retamal	09-01-2016	11-30-2016	X	X	X	X

The database on salinity was reduced to one set of data using the daily average. Because both monitoring networks have the same monitoring purpose, measurements and reporting procedures, the database was screened and reduced into a consistent data set prior to completing the analyses.

The screening method check used to identify spurious data in salinity database was performing range checks. Range checks pointed out abnormally high and low values for a given parameter. Salinity data were examined by the following techniques: histogram, scatter plots and cumulative distribution.

After the screening range checks in salinity, the database exhibits the following three characteristics:

1. Salinity database has the shape of the Gaussian form as shown in Figure 5.

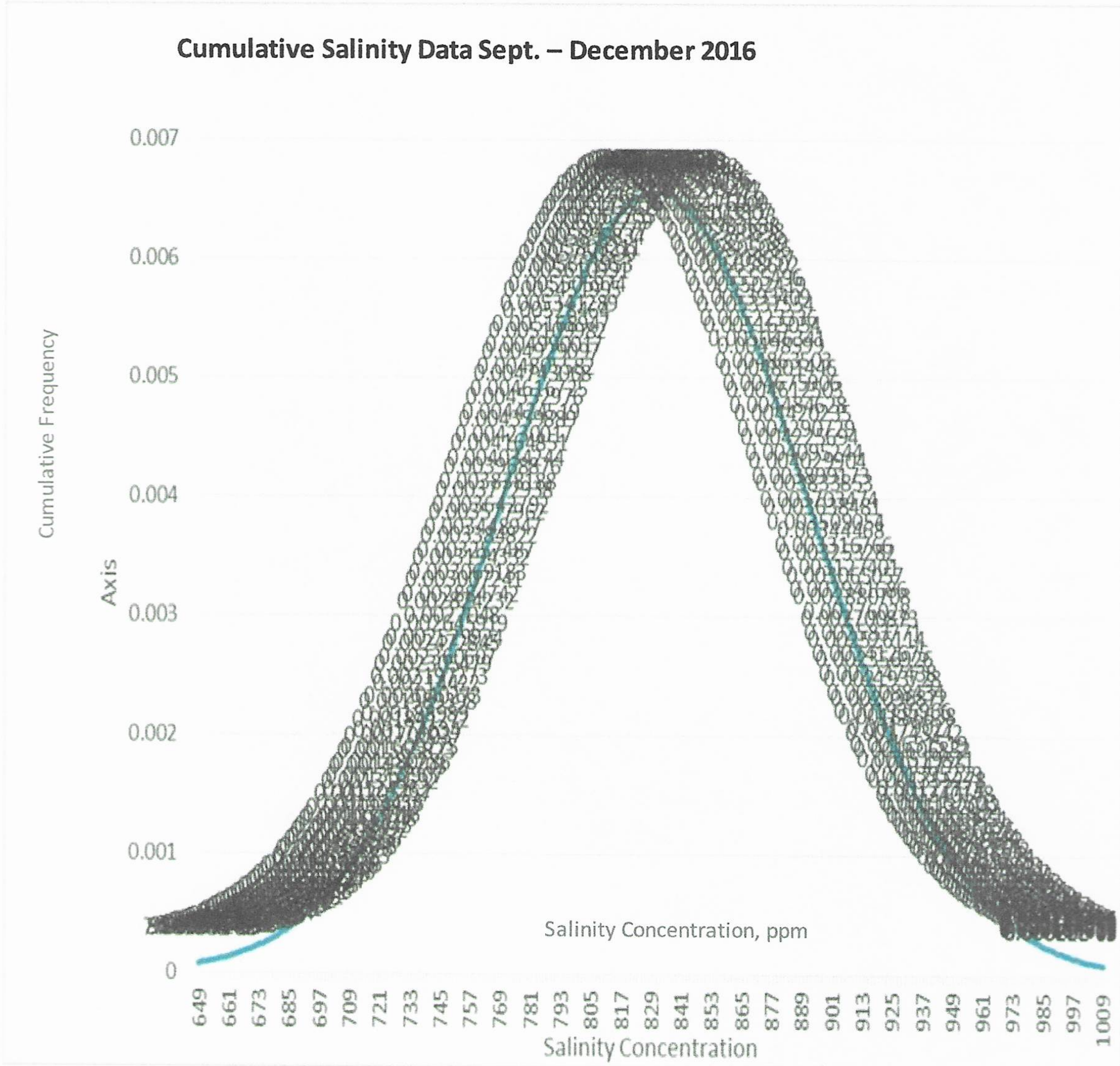

Figure 5 Cumulative salinity data from September - December 2016

2. In the box plots, the salinity database does not show low or high outliners (Figure 6).

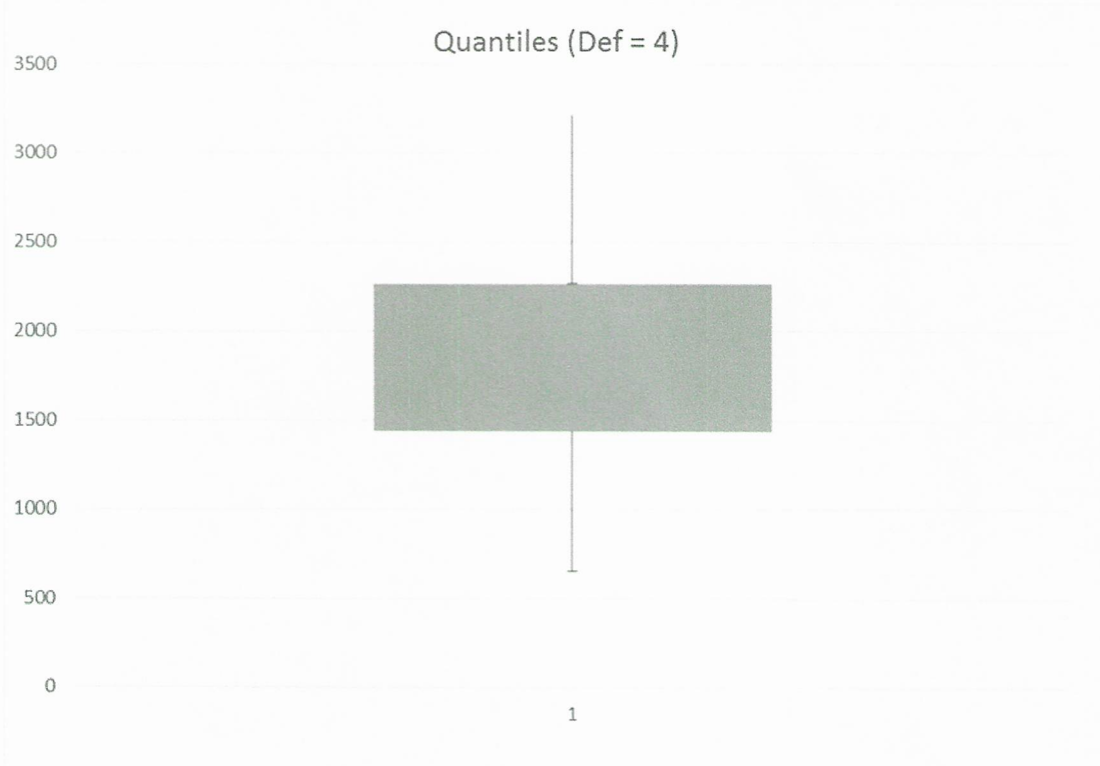

Figure 6 Box Plots of daily salinity from September-December 2016

3. The salinity database shows a skewed histogram (Figure7)

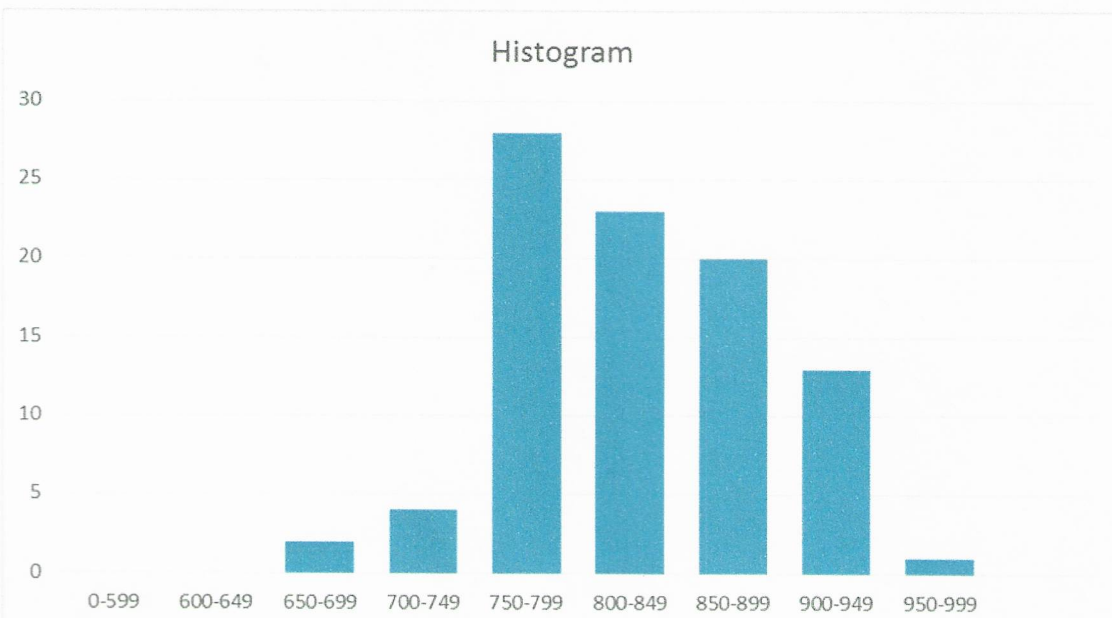

Figure 7. Salinity concentration histogram from September - December2016

4.2.4 Data Quality

The screening procedure used did not identify any questionable values in the salinity database. Consequently, the original database is considered data with acceptable quality.

4.3 State of Water Quality Based on Salinity

The mean obtained during the three months on salinity at Anzalduas Dam was 822 ppm and comparing it with the permissible limits for classes of irrigation water, Anzalduas Dam's reservoir is considered as Class 3, with permissible concentration on ppm of salts.

Using the formula to convert ppm of salinity obtained in the research to µmhos or EC value:

Salinity = Salinity in ppm/0.64

Substituting:

Salinity value:821.66 ppm

Formula: Dividing the parts per million values by 0.64

As a result, the salinity is 821.66 ppm or 1284 µmhos

The value obtained of 1284 µmhos corresponds in the classification of water used for irrigation as water permissible according to the permissible limits for classes of irrigation water in Table 7.

Table 7. Classification of irrigation water based in total dissolved solids.

Permissible limits for classes of irrigation water		
Classes of Water	Concentration, total dissolved solids	
	Electrical Conductivity µmhos*	Gravimetric ppm
Class 1, Excellent	250	175
Class 2, Good	250-750	175-525
Class 3, Permissible[1]	750-2,000	525-1,400
Class 4, Doubtful[2]	2,000-3,000	1,400-2,100
Class 5, Unsuitable[2]	3,000	2,100

*Micromhos/cm at 25 degrees C.

[1]Leaching needed if used

[2]Good drainage needed and sensitive plants will have difficulty obtaining stands

Note. The chart shows the different classes of irrigation water. Data from Department of Agricultural Engineering. The Texas A&M System, College Station, Texas.

4.4 Climatology

Because the temperature database has minimum and maximum values reported daily in its original database, a daily average was considered in the evaluations. Basic statistics were prepared for temperature, evaporation and volume rate such as variability of each parameter versus time. "Getting to know the data through simple plots and tables can quickly reveal high-level patterns in the data" stated Bhaskaran, K., Gasparrini, A, Hajat, S., Smeeth, L., & Armstrong, B. (2013). The variability graphs are showed in the figures 8 through 10.

4.4.1 Temperature over time variability

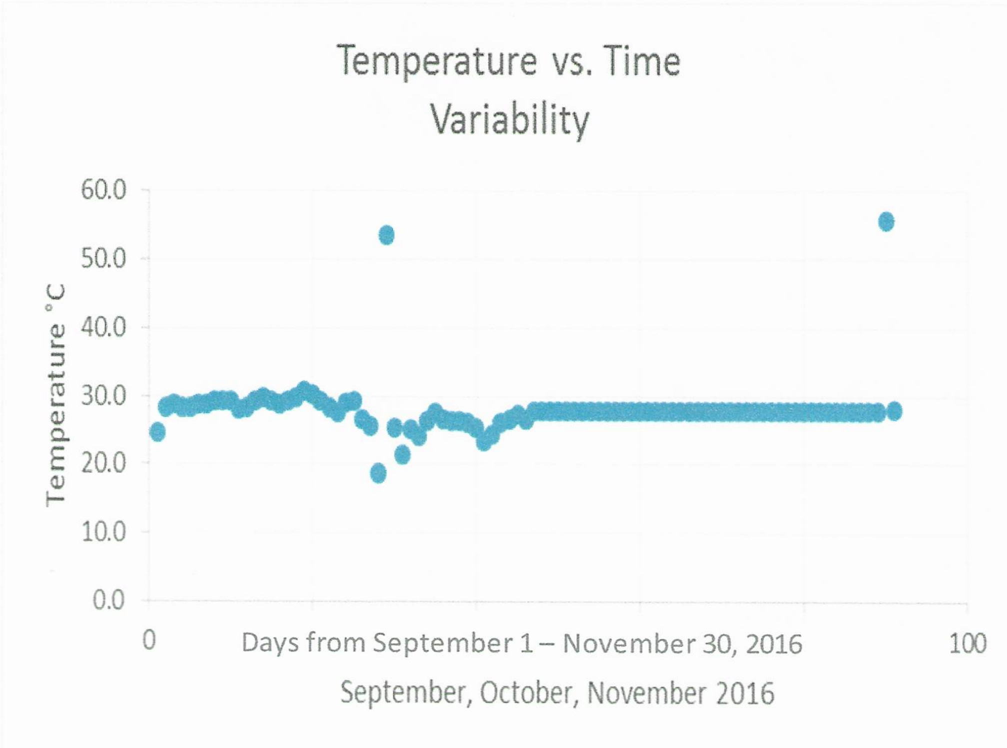

Figure 8. Variability of temperature over time from September – December 2016

4.4.2 Temperature over time variability

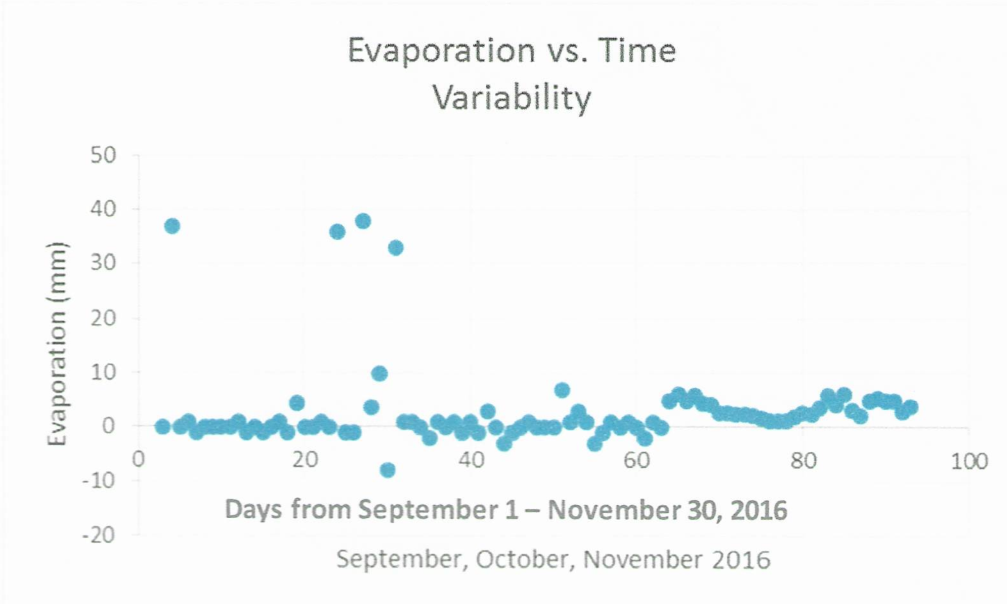

Figure 9. Variability of evaporation over time from September – November 2016

4.4.3 Flow rate analysis using variability

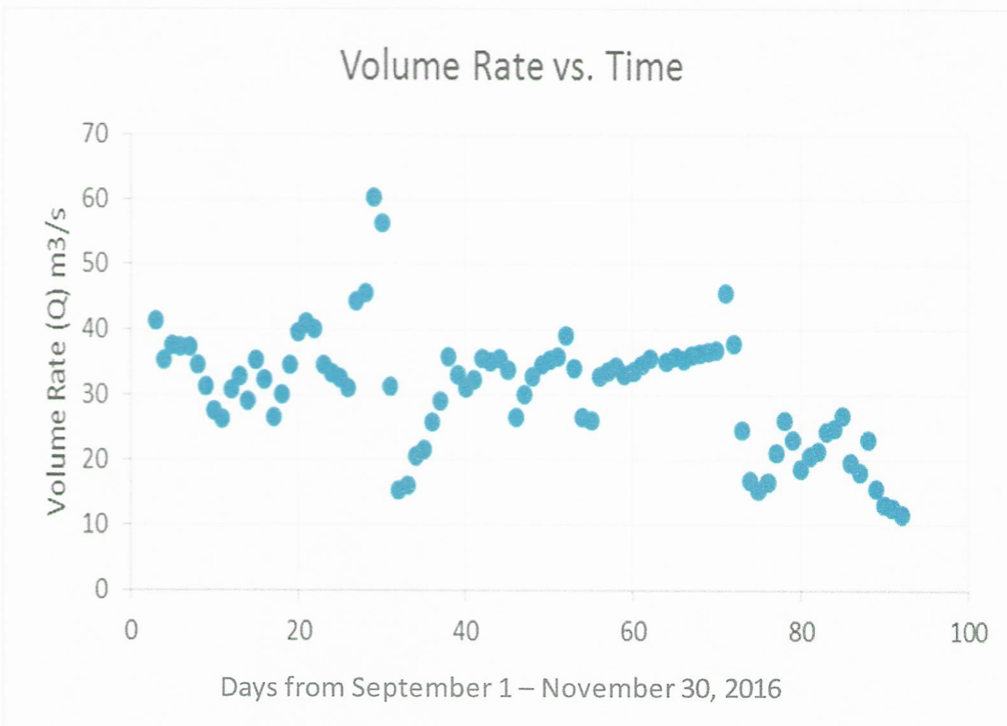

Figure 10. Variability on flow rate and time from September – December 2016.

CHAPTER 5

STATISTICAL ANALYSIS

5.1 Statistics for Salinity database

It is very useful to analyze the daily salinity concentration data observed at the three monitoring stations using ANOVA. The analysis' results inform that means on 6:00 AM, on 12:00 PM and 6:00 PM are not equal as shown in Table 8.

Table 8. ANOVA on salinity database from September-December 2016

Anova: Single

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	128	8256	64.5	1376
Column 2	128	104600	817.1875	20634.54724
Column 3	128	88098400	688268.75	23964546417

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4.03719E+13	2	2.01859E+13	2526.971426	1.29E-220	3.019411119
Within Groups	3.0435E+12	381	7988189476			
Total	4.34154E+3	383				

Table 8. Cont.

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	1.02E+1 2	127	8E+09	1.00253 7	0.48661 4	1.28065 8
Columns	4.04E+1 3	2	2.02E+1 3	2529.10 9	2E-168	3.03134 4
Error	2.03E+1 2	254	7.98E+0 9			
Total	4.34E+1 3	383				

5.2 ANOVA test

Reading the ANOVA one-way table in the source of variation between groups, the p-value is 1.29E-, which turns out to be 1.29 times 10 to the power of negative ten. This value is extremely small number and the one-way ANOVA conclusion is to reject the null hypothesis Ho.

Remembering that a one-way ANOVA uses the following null and alternative hypotheses:

- Ho: All group means are equal.
- HA: All group means are not equal.

The test concluded that the means in the three different hours of lecture, which are 6 am, 12 pm, and 6 pm, are not equal. The mean of the 6 pm hour is lower than the mean of the other two lectures. The analysis suggests that the flow rate in the Rio Grande is diluting the salts accumulated during the day.

CHAPTER 6

MONITORING STATION-HIDALGO, TX.

Other valuable data on salinity or specific conductance and temperature in Anzalduas dam is found in the USGS webpage.

The link for the cited site is the following:

https://urldefense.com/v3/__https://waterdata.usgs.gov/monitoring-location/08469175/*parameterCode=00010&period=P7D__;Iw!!DfwEdKd4Yj-C2yU!mfmj7wbH2FEDilzdkD9u_3MQ3uJRcR2EpvXCxZwMo5Co_HE78BFT7kSo-RKgGSMMdR8KoWO9cjnQ04Jb0oy75NuzpjlUCghmEapy$

6.1 Specific Conductance in microsiemens per centimeter

Analyzing concentrations of specific conductance in the graph proportioned by USGS during August, 2022 to August, 2023, it shows that the concentration of salinity decreases in the months of September until December, which are the irrigation's months. The decrease in the concentration of salinity can be as a result of the dilution process in the Rio Grande River. In contrast the graph shows an increase in the concentration of salinity in January and decreasing again during the new irrigation's cycle, which is in February to May as it is showed in Figure 11.

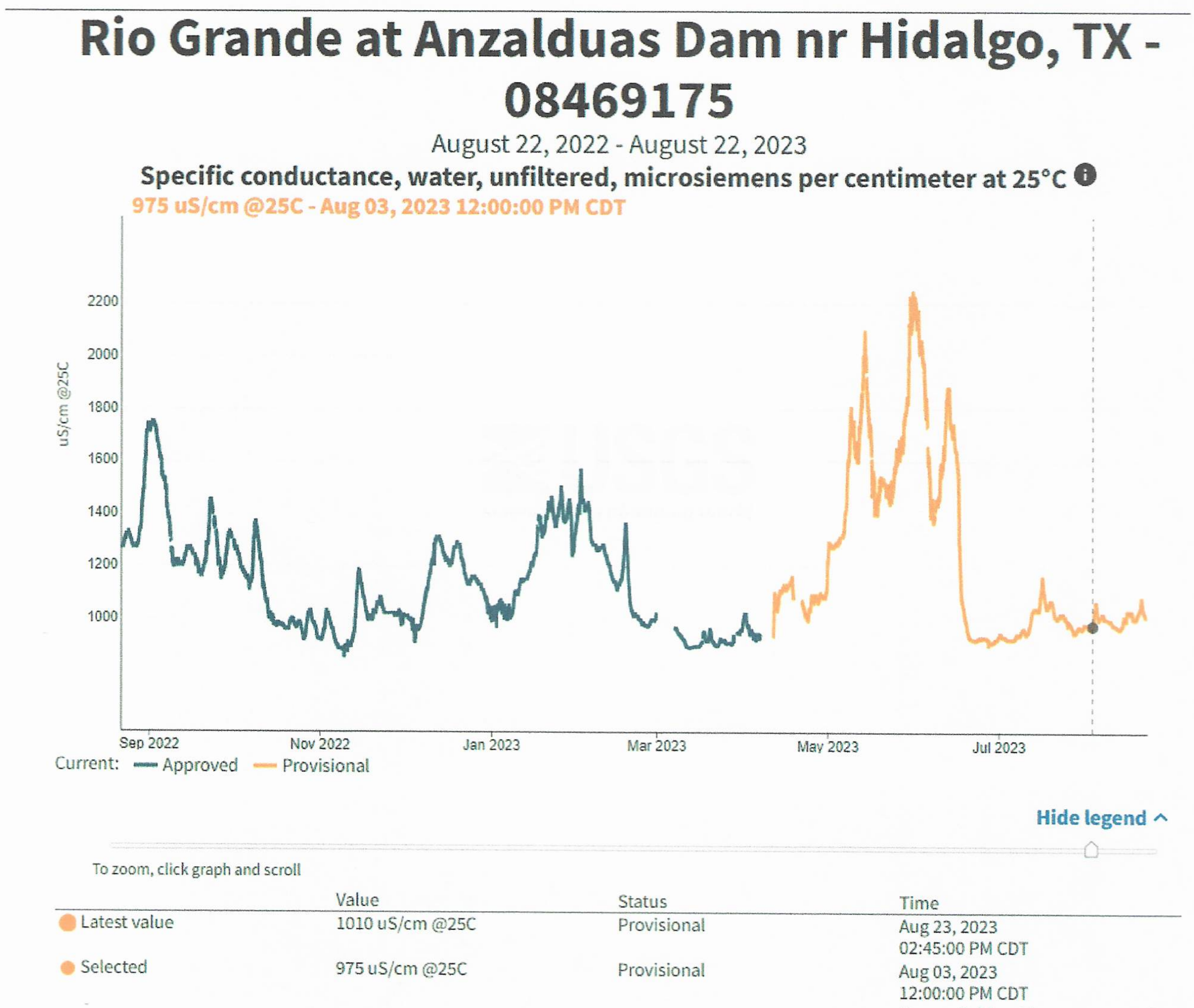

Figure 11. Specific conductance at Anzalduas Dam near Hidalgo, TX-08469175

6.2 Temperature, water, ° F data

The USGS monitoring station near Anzalduas Dam and located in Hidalgo, TX shows a decrease of the water's temperature in Celsius degrees from last week of September until

December and ending in mid-January with 13 Celsius degrees. Moreover, the temperature increases in February from 16 to the 40's Celsius degrees in summer months. The summer months in the South Texas are around 40-43 Celsius degrees with a sensation of 3-4 more degrees and the graph shows the temperature in the water's reservoir only. Figure 12 shows the temperature's registration

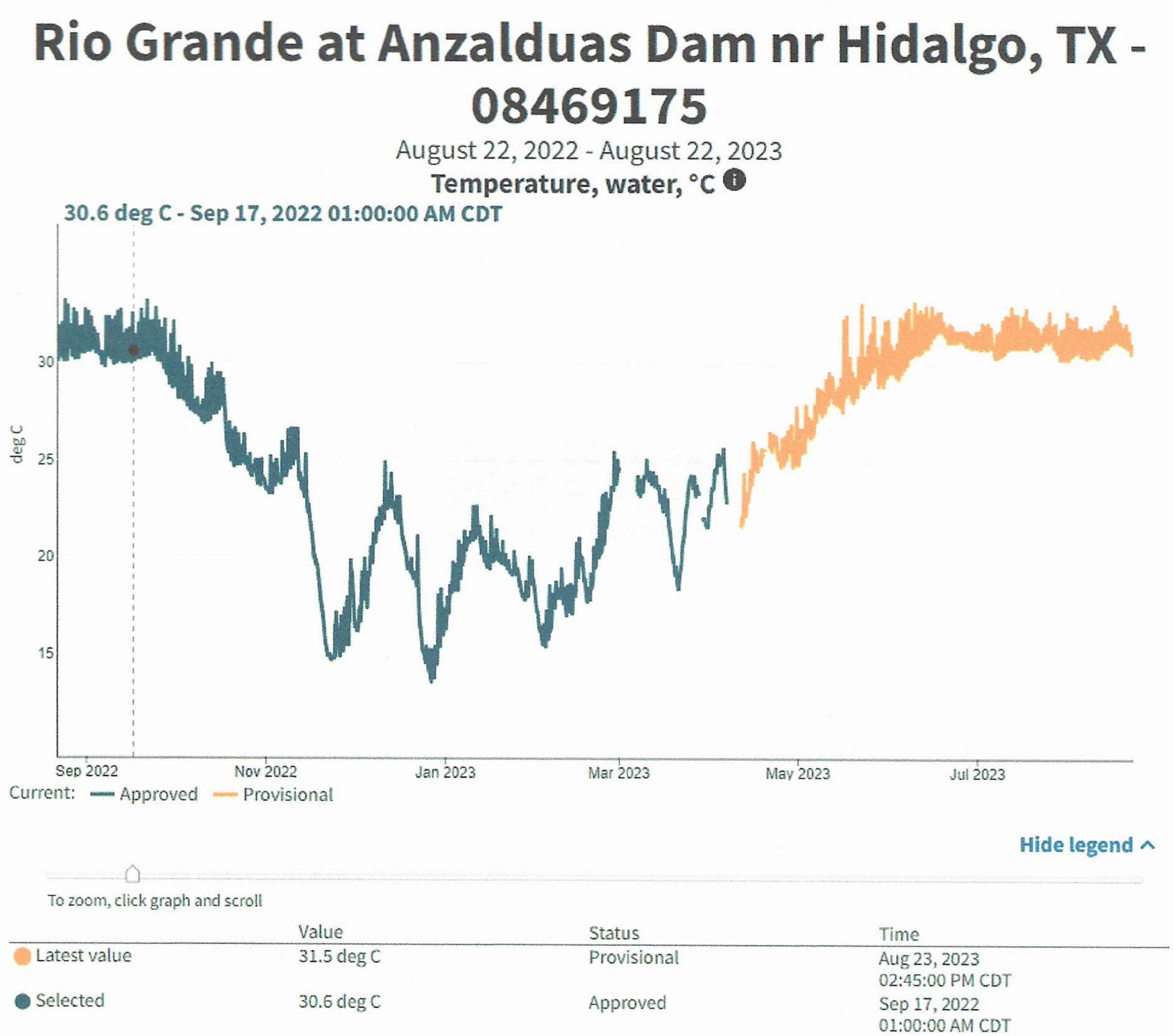

Figure 12. Water Temperature at Anzalduas Dam near Hidalgo, TX.

CHAPTER 7
RESULTS

7.1 Salinity

Because the monitoring networks between both commissions in Mexico and USA in the Anzalduas's reservoir are non-independent and they have the same collection protocols, it was possible to assess the quality of the final database. Previous studies on salinity have focused on the patterns on Falcon Dam and Brownsville. Data collected for these analyses typically were collected at monitoring stations spaced on the order of 220 and 90 miles from Anzalduas Dam. This spacing may be adequate for assessing regional trends but it is inadequate for helping to quantify local effects.

The conclusions include:

- The Water Quality Based on Salinity reports that the Anzalduas Dam's reservoir is considered as Class 3, with permissible concentration of salts for the classification as water for irrigation.
- Salinity increased during the first two weeks on September in Anzalduas Dam's reservoir and decreased after the third week of September. The flow rate passing through Anzalduas Dam increased during the seasonal Fall-Winter irrigation, which starts in the last weeks of September. Consequently, the low flow before the seasonal irrigation increases the concentration of salinity as it is shown in the lecture of the monitoring stations. This conclusion was corroborated with the lectures of the salinity concentrations showed in the USGS in the monitoring station located 5 miles from the Amzalduas Dam in Hidalgo, TX.

- Average mean on Salinity concentration showed the highest concentration on November 20, 2016 with value of 951 ppm. The lowest Salinity mean's concentration was observed on December 11, 2016 with value of 653 ppm. It is possible that the concentration of salinity decreases because the salts accumulated in the upper section of the river had moved downstream due the increase of the flow in the seasonal irrigation. The salts are diluted as the flow rate increases. A comprehensive water and salt balance analysis is needed to explain this situation. Analyzing data from the monitoring station located in Hidalgo, TX, the less concentration's pike of salinity is showed in December.
- Salinity concentration exhibited a decrease during the afternoon (6: 00 PM) monitoring. The lecture of lower concentration of salinity during the afternoon is related to the increase of flow rate during the seasonal irrigation. It may be accounted for by dilution.

  Analyzing another monitor station low stream of Anzalduas Dam located in Hidalgo, TX, shows a decrease of specific conductance at 25 degrees Celsius during the afternoon. It reinforces the data collected of the monitoring stations described in this research.

  The results show that with 95% percent of confident level the means of salinity during the three time's monitoring values in the day in the Anzalduas Dam's reservoir are not equal. The ANOVA analysis rejected the null hypothesis Ho.
- Linear Regression Forecast between Salinity and Flow Rate shows an increase on Salinity concentration in a long term of years.

- The concentration of salinity is independent of the temperature in Anzalduas Dam. Analyzing the values in the USGS graphs y analyzing the data, the concentration of salinity decreased in the last months of the year and the temperature decreased in the last months too.

7.2 Temperature, Evaporation and Flow Rate Findings:

The temperature vs. time graph (Figure 8) showed no variation between temperatures (30°C) during the first three weeks in September. The higher variability is exhibited at the end of September and October when the temperature decreased below 30°C. The graph determined no variation for almost 45 days on October and November. The temperature's graph data obtained in the monitoring station located at Hidalgo, TX shows an increase of temperature in the afternoon compared to the morning temperature. It is a result of the temperature observed in a subtropical region.

In evaporation vs. time (Figure 9) the plots showed no variability in the month of September. The values of evaporation for September were zero and below zero mm. For the month of October, it showed higher variability around the values of 5 mm. The graph showed no variability for almost 45 days in November and half of October.

Volume rate exhibited no variability during three weeks of September (Figure 10). After the third week on September and on October the graph showed that the flow rate increased with time. Finally, in some weeks of October and November, the variability decreased considerably with time.

CHAPTER 8

DISCUSSIONS

The importance of determining the salinity in the Anzalduas Dam is based on the impact of salts and other substances that affect the quality of water used for irrigation or drinking including the aquatic biota.

Firstly, salinity is a measure of the number of salts in the water. Ions increase salinity as well as conductivity, the two measures are related. Moreover, solids can be found in nature in a dissolved form. Salts that dissolve in water break into positively and negatively charged ions. Conductivity is the ability of water to conduct an electrical current, and the dissolved ions are the conductors. The major positively charged ions are sodium (Na^{+}), calcium (Ca^{+2}), potassium (K^{+}) and magnesium (Mg^{+2}). The major negatively charged ions are chloride (Cl^{-}), sulfate SO_4^{-2}), carbonate (CO_3^{-2}) and bicarbonate (HCO_3^{-}).

Nitrates (NO_3^{-2}) and phosphates (PO_4^{-3}) are minor contributors to conductivity but those ions they are very important biologically.

Observing in the histogram of salinity at Anzalduas's Dam Reservoir (Figure 7), it shows that the highest salinity observed in 90 days is in the range of 750-799 ppm in a frequency of 28 occurrences of 90. Those data allowed us to know that the water quality of the reservoir has a quality permissible to be used for irrigation.

Analyzing data of specific conductance and temperature, it is shown that temperature is independent of the specific conductance values obtained in the dam's reservoir.

CHAPTER 9

CONCLUSIONS, LIMITATIONS AND FUTURE WORK

The decrease of salinity concentration monitored in the afternoon, 6:00 PM, at Anzalduas Dam supports the general understanding that salinity is not influenced by temperature. The decrease of salinity's concentrations at the end of the day was an interesting result.

The database compiled in this study provides details on Anzalduas Dam's salinity and its water quality of irrigation including the variability of temperature, evaporation and volume rate. The temperature data does not exhibit great variability over time. The region of South Texas, which the Anzalduas Dam is located, has a subtropical weather and the fall's temperature varies around 25-30 Celsius degree with an exception of some dropping days with temperature below 20 Celsius degrees.

The figure on evaporation and time shows no great variability on evaporation during the months of September and October. In contrast, during the month of December the evaporation increased in the first week, decreased for two weeks and increased during the last week of December.

The volume rate's data and time shows that the volume rate (Q) during the months of September, October and the first week of December was between the range of 30 and 40 m^3/s. Those water flow volumes are open to be used in the irrigation's time during Fall's irrigation season in the valley, which is the study area. In contrast, the volume rate decreased during the first week of December to a range of 10-20 m^3/s

It concludes that this study can be used to help answer some questions concerning the effect of salinity at Anzalduas Dam.

The inability to continue monitoring the upper and lower water in the dam reservoir is due to the unsafe conditions created by the migration of people to US and related issues. In addition, the Mexican cartels pass their illegal drugs using the Rio Grande River as route to US.

It is highly recommended to prepare another study with the inclusion of more physical, chemical and microbiologic analysis in the future.

REFERENCES

Ayres, R.S. and D. W. Westcot. (1970). *Water quality for Agriculture. Irrigation and drainage Paper No. 29.* Food and Agriculture Organization of the United Nations. Rome

Bhaskaran, K. Gasparrini, A, Hajat, S., Smeeth, L., &Armstrong, B. (2013). *Segmented Regression of Interrupted Time Series. International Journal of Epidemiology, 42(4), 1187-1195. Retrieved from:*

https://bvasiles.github.io/empirical-methods/spring-2021/pages/apr08-its.html

Daily Mail. (2017). *Texas Police Alerted to Shooting on the Rio Grande.* Ariel Zilber.

April 21, 2017. Retrieved from:

http://www.dailymail.co.uk/news/article-4318756/One-dead-two-wounded-shooting-Rio-Grande. html#ixzz4etZL9iXX

Fipps, Guy. (1998). *Irrigation Water Quality Standards and Salinity Management Strategies.* Department of Agricultural Engineering. The Texas A&M System, College Station, Texas. Retrieved from: Soiltesting.tamu.edu/publications/B-1667.pdf

Google Earth Maps. (2017). *Anzalduas Dam Aerial View Picture.*

Retrieved from: www.google.com googleearth/maps.

International Boundary and Water Commission (IBWC)-USA. (2016). *2016 Basin Highlights Report.* Retrieved from:

http://www.ibwc.gov/crp/documents/2016

International Boundary and Water Commission (IBWC). United States and Mexico/US Section (2023). *Mission*

Retrieved from:

http://.ibwc.gov/#reports

Kelley, R. (2016). *Anzalduas Dam helps tame historic Rio Grande.* Valley Morning Star. Newspaper. Sunday, February 28, 2016. Retrieved from: htttp://www.valleymorningstar.com/news/local_news

Instrument (2017). *About Conductivity/Resistivity/Salinity/TDS Meters*. Retrieved from: http://www.instrumart.com/MoreaboutCategory

International Boundary and Water Commission (IBWC)-Mexican Section. CILA. (2016). *Monitoreo de la Salinidad por Conductancia en Diferentes Puntos del Rio Bravo.* (2016). Non-published Data.

Miyamoto, S., Fenn, L.B., & Swietlik, D. (1995). *Flow, Salts, and Traces in the Rio Grande: A Review*. Texas Water Resources Institution (TWRI), Texas A&M University System, College Station. MP 1764, 30 pp.

USGS Science for a changing world (2023). *Rio Grande at Anzalduas Dam nr Hidalgo, TX-08469175*. Retrieved from: https://waterdata.usgs.gov/monitoring-location/08469175/#parameterCode=00010&period=P7D